SECTION 23 05 93 - TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 - GENERAL

1.1 SYSTEM PERFORMANCE REQUIREMENTS

A. Require general, mechanical and electrical contractors to coordinate and cooperate with the TAB contractors as necessary to allow them to perform work.

B. Items such as start-up, initial testing, cleaning, calibration of controls, electrical testing, etc., are to be completed prior to the commencement of TAB work.

C. Submit name of balancing and testing agency with resume of the agency, including qualifications of personnel to be used and authority and responsibilities of personnel.

D. Product data shall be submitted, in accordance with Section 23 00 00, for each of the following :

1. Procedure Submittal: Prior to commencing work, submit, for approval, a written procedure of how balance will be performed and a description and manufacturer's name of equipment and instruments to be used. The submittal shall include, but not necessarily be limited to the following:
    a. List of preliminary checks to be performed at the job site such as confirmation that manual volume dampers are present, filters are installed, frequency drive units operational, location of control sensors, etc.
    b. Identify how the air outlets will be measured and the type of instruments to be used.
    c. Locations of pilot traverses and the type of instruments to be used.
    d. Modes of operation that the system will be placed in during balancing and testing, i.e., full cooling and heating, maximum and minimum outside air flows, maximum and minimum sash positions for fume hoods, toilet fans on or off, etc.
    e. Position of doors and windows during balance, i.e., some labs should be balanced with doors shut.
    f. Operating static pressures for terminal devices and pressure sensors for controlled devices.
    g. Method of adjusting outside and return air quantities at air handling units.
    h. Initial test procedures for preliminary balance.
    i. Final test procedures.
    j. List of deficiencies in mechanical system that could hinder the balance work such as missing or leaky dampers, incomplete systems, inadequate fans, etc.
    k. Sample of data sheets and test forms to be used in final report.
    l. Identification and manufacturer's name of equipment to be used on project and proof of last calibration on each piece.
2. Progress Report(s) – Report, in writing, any deficiencies or problems with air or water systems that have affected balance work. Include items that affect system performance such as broken thermostats, damaged ductwork, excessive noise, etc.

1.2 QUALITY ASSURANCE

A. Test, adjust, and balance systems in accordance with ASHRAE Applications Handbook. For NEBB certification, comply with "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems." For AABC certification, comply with "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems."

B. TAB contractors shall present to the University Project Manager and general contractor, proof of current equipment certification approved by National Institute of Standards and Technology.

C. Testing Agency Qualifications: Agency shall be NEBB or AABC certified in testing and balancing disciplines required for this project. Work shall be performed under direct supervision of professional engineer, NEBB, or AABC certified supervisor.

D. Guarantee of Work: TAB contractor shall guarantee the balancing for a period of 90 days from date of acceptance of final report. During this period, the TAB contractor shall make personnel available at no cost to the university to verify measurements and/or correct deficiencies in the balance. During this period, emergency adjustments shall not void this warranty.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.1 INSTALLATION, GENERAL

A. Pre-Balancing Conference: Before beginning testing, adjusting, and balancing procedures, schedule and conduct a conference with University Project Manager, Facilities Operations Representative(s) and representatives of installers of mechanical and control systems. Conference objective is final coordination and verification of system operation and readiness for testing, adjusting, and balancing, and assigning testing responsibilities of each installer.

B. Systems shall be complete and fully operational prior to beginning procedures. Insure all items such as thermometer wells, pressure test-cocks, access doors, etc., are installed to facilitate tests and adjustments.

C. Put all heating, ventilating, and air conditioning systems and equipment into full operation and continue operation during testing and balancing.

D. Before air balance work is started, check system for duct leakage, install a complete set of clean filters, check for correct fan rotation and equipment vibration, and check automatic dampers for proper operation. Set volume control dampers and outlets in wide open position. Ensure fire dampers are open and that return air paths are not obstructed.

E. Prior to performing hydronic balance work; check system for plugged strainers, proper pump rotation, and proper control valve installation and operation. Check air vents at high points of systems to ensure all are installed and operating freely (automatic type) or bleed air completely (manual type); and verify proper flow meter and check valve installation and proper system pressure.

F. All throttling devices and control valves shall be set open.

G. Performing Testing, Adjusting, and Balancing:
   1. Cut insulation, ductwork, and piping for installation of test probes to minimum extent necessary to allow adequate performance of procedures.
   2. Patch insulation, ductwork, and housings, using materials identical to those removed.
   3. Reseal ducts and piping, and test for and repair leaks.
   4. Reseal insulation to re-establish integrity of the vapor barrier.
   5. Mark equipment settings, including damper control positions, valve indicators, fan speed control levers, and similar controls and devices, to show final settings. Mark with paint or other permanent identification materials.
   6. Retest, adjust, and balance systems subsequent to significant system modifications, and resubmit test results.

H. Sequencing and Scheduling:
   1. Systems shall be fully operational before beginning procedures.

2. Conduct tests in the presence of the University Project Manager after providing 7-day notice before any test is to be conducted. Provide water and electricity required for tests. Determine that all dampers, registers, and valves are in a set or full open position.

I. Balancing:
   1. Water Balance:
      a. Balance water piping and snow melt systems to produce water quantities within 5 percent of design flow rates for cooling water systems and within 10 percent of design flow rates for heating water systems.
      b. Hydronic systems shall be proportionally balanced, ensuring the path to one terminal is fully open. Total system flow shall be adjusted at pump by restricting discharge balancing valve.
      c. Indicate and record final position of balancing valves.
      d. Primary-Secondary Flow Systems: Balance primary system crossover flow first, then balance secondary system.
      e. Pumps:
         1) Verify pump impeller size and pump rotation.
         2) Measure flow.
         3) Measure inlet and outlet pressures.
         4) Measure motor full load amperage at design flow and shut-off condition.
      f. Heat Exchangers:
         1) Measure water flow through all circuits.
         2) Measure inlet and outlet water temperatures.
         3) Calculate capacity in btu-h.
         4) Measure inlet steam pressure. Check setting and operation of automatic temperature-control valves and pressure reducing valves.
         5) Record safety valve settings.
         6) Verify operation of steam traps.
      g. Chillers:
         1) Balance water flow through each evaporator and condenser with all pumps operating. With only one chiller operating in a multiple chiller installation, do not exceed flow for maximum tube velocity recommended by chiller manufacturer. Perform tests and record data with each chiller operating at design conditions for:
            a) Evaporator and condenser water entering and exiting temperatures, pressure drop, and water flow.
            b) Evaporator and condenser refrigerant temperature and pressures.
            c) Calculate capacity in tons.
         2) For air cooled chillers, verify condenser fan rotation and record fan data, including number of fans and entering and exiting air temperatures.
      h. Cooling Towers:
         1) Shut off makeup water for duration of test and ensure makeup and blow-down systems are fully operational after tests. Perform tests and record data for:
            a) Condenser water flow to each cell of cooling tower.
            b) Entering and exiting water temperatures.
            c) Wet, and dry, bulb temperatures of entering and exiting air.
            d) Condenser water flow rate recirculating through cooling tower.
            e) Cooling tower pump discharge pressure.
            f) Fan cfm and static pressure for each cell.
      i. Heat Transfer:
         1) Measure entering and exiting water temperatures and pressures.
         2) Measure gas flow rate.
         3) Measure water flow.
         4) Calculate capacity in btu-h.
      j. Water Coils:
         1) Measure entering and exiting water temperatures and pressures.
         2) Measure water flow rate.

3) Measure entering and exiting dry, and wet, bulb air temperatures.
4) Measure airflow. Measure air pressure drop. Calculate capacity in btu-h.

k. Finned Tube Radiation:
1) Measure entering and exiting water temperatures.
2) Measure water flow rate.
3) Calculate capacity in btu-h.

l. Evaporative cooling:
1) Adjust water flow across media per manufacturer.
2) Adjust bleed rates.
3) Adjust fill rates.

2. Air Balance:
a. Balance duct system to produce air quantities within 10 percent of indicated value.
b. Dampers: Adjust automatic damper linkages to provide air flow quantities shown. Check all automatic dampers in normal operation to verify proper operation. Verify return, relief air, and fresh air intake dampers operate as designed to produce desired room comfort.
c. Place all fans (supply, return, and exhaust) in operation. Load or restrict filters to increase pressure drop to 50% of span between initial pressure drop and final recommended pressure drop for setting final air flows for fans. Check the following:
1) Motor amperage and voltage to guard against overload.
2) Fan rotation.
3) Operability of static pressure limit switch.
4) Automatic dampers for proper position.
5) Air and water resets operating to deliver required temperatures.
6) Air leaks in casing and in safing around coils and filter frames.
d. Traverse Main and Branch Ducts: Perform pitot traverses for fan total air flows including traverses for hot and cold decks, for each zone in multi-zone systems and for each floor. Mark locations of pitot traverses on reduced drawings in final report.
1) Note temperature and barometric pressure. Corrections shall be made for systems operating at 5200-foot elevation.
2) After establishing total air being delivered, adjust fan speed to obtain design airflow. Check power and speed to see that motor power and critical fan speed have not been exceeded.
3) Proportionally adjust branch dampers until each has proper air volume.
4) With all dampers and registers in system open and with supply, return, and exhaust fans operating at design cfm or speed, set minimum outdoor and return air ratio.
5) After minimum outside air damper has been set for proper percentage of outside air, take another traverse of mixture temperatures. Notify the University Project Manager and note in balancing report if variation from average is more than 5 percent.
e. Adjust system with mixing dampers positioned for minimum outside air.
f. Balance terminal outlets in each control zone in proportion to each other. Use branch dampers for major adjusting and terminal dampers for trim or minor adjustment only.
g. Balance constant volume reheat systems in one mode, namely design airflow.
h. Balance constant volume dual duct systems at the boxes for full cooling and full heating air flows. Balance the fan with all the boxes on full cooling. Record the total fan supply with the boxes on full cooling.
i. Balance VAV fans by placing a certain number of the VAV boxes in full cooling mode. This number shall be equal to the system diversity and shall include boxes that are at the end of the system, that are on duct branches with high static loss and serve critical areas. With the system in this mode the fan shall be sheaved to maintain the static pressure required to control the worst case VAV box.
j. Once total design air has been balanced in branches and at outlets, verify and record the following:
1) Fan motor amperage.
2) Fan speed
3) Fan cfm.

4) Fan outlet velocity.
5) External and total static pressure.
6) Supply, return, mixed, and outside air temperatures.
7) Percent outside air under minimum damper position.
8) Static pressure across each component (intake, filters, coils, and mixing dampers).
9) Take a final duct traverse.

k. Final adjustments shall include, but not be limited to the following:
1) Adjust RPM on belt drive fans. Include sheave and belt exchange to deliver air flow within limits of installed motor horsepower and mechanical stress limits of the fan. Determine limiting fan tip speed before increasing RPM. Final fan speed setting shall allow for filter loading and shall establish proper duct pressures for operation of zone cfm regulators.
2) Replace all variable pitched sheaves with fixed pitched sheaves. This includes such devices as fan coils.
3) Adjust rpm on Direct Drive Fans:
a) For motors with speed taps, set fan speed on tap which most closely approaches design cfm. Report tap setting on equipment data sheet as high, medium, or low.
b) For motors with speed control, set output of fan at design cfm by adjusting control. Ensure the fans restart after shut down. Increase setting as required for proper setting. Mark control to indicate final setting position.
4) Terminal Boxes:
a) For variable air volume (VAV), constant volume boxes, or dual duct boxes, set regulators to provide design minimum and maximum airflow rates. Adjust thermostat to assure proper damper operation.
b) For VAV, or constant volume boxes with reheat, set regulators to provide design minimum and maximum air flow rates. Check control sequence operation to assure proper sequencing.
c) Air flow performance of boxes for both primary and secondary balance settings shall be verified by flow measuring hood measurements at diffuser outlets.

3. Fume Hood Balancing:
a. Balance fume hood exhaust fans to meet face velocity requirements. The face velocity shall be maintained at a face velocity as required by the project specific equipment, the manufacturer and coordinated with the University Project Manager and EH&S.
b. Balance hoods with the building supply and exhaust systems in normal operation, with doors and windows in typical position and hoods empty and clean. Record these conditions in report.
c. Set horizontal sash hoods at 12 inches or greater. Adjust the fan to provide the required face velocity measured at a minimum of nine centerline measurements equally spaced at sash plane using a hot wire anemometer. The average of the nine measurements shall be corrected for temperature and altitude and recorded. Place a sticker furnished by the University Project Manager at the approved sash height.
d. Raise the sash to find the height where the design face velocity is achieved. Mark this height with a second sticker furnished by the University Project Manager. If the sash height is below the acceptable working height, the hood will not pass acceptance.
e. Set vertical sash hoods with a 12-inch or greater space centered in front of the hood. If an odd number of sashes exist, the opening shall be the most distant from the exhaust point inside the hood. Adjust the fan to provide the required face velocity measured at a minimum of nine centerline measurements equally spaced at sash plane using a hot wire anemometer. The average of the nine measurements shall be corrected for temperature and altitude and recorded.
f. Move the sash to find the position where the design face velocity is achieved. Mark this position with a second sticker furnished by the University Project Manager.
g. Indicate face velocity in FPM on fume hood for record.

h. Adjust spaces with pressure gradients or directional air flow requirements to meet standards as well as designated air flows. Verification of performance shall be made with pressure gradient measurements, smoke tests in presence of the university Facilities Operations representative, or hot wire anemometer across door cracks etc. Pressure differential measurements are preferred unless gradient is too small (under 0.01 inches w.c.) by standard.
i. Hoods to be tested and balanced in accordance with ASHRAE 110 and SEFA Standards.

4. Bio-Safety Cabinets: Balance all thimble-connected Class II, A2 or A3 Bio-Safety Cabinets to meet manufacturer requirements and NSF 49.
5. Smoke Systems: Test smoke management systems per NFPA 92A.
6. Equipment Motors: Record the following information for every motor and include information with the appropriate equipment.
   a. Motor horsepower and rpm.
   b. Nameplate and measured voltage and amperage, each phase.
   c. Motor Starters and Thermal Heaters: Check for correct sizing for proper motor protection on magnetic and manual starters.
7. Building Automation System: Coordinate with Section 23 09 00. Inspect temperature control systems for proper sequence of operation and approximate calibration. Report any deficiencies. Include written certificate in balance report that temperature controls function properly.
   a. Verify proper operation of devices. Verify that all controllers are calibrated and operational.
   b. Check location of transmitters and controllers. Note adverse conditions that would affect control and suggest relocation as necessary to University Project Manager.
   c. Note settings on controllers. Note discrepancies between set point for controller and actual measured variable.
   d. Verify operation of all limiting controllers, positioners, and relays (e.g., high and low temperature thermostats, high and low differential pressure switches, etc.).
   e. Activate controlled devices, checking for free travel and proper operation of stroke for dampers and valves. Verify and note normally open (NO) or normally closed (NC) operation.
   f. Verify sequence of operation of controlled devices. Note line pressures and controlled device positions. Correlate to air or water flow measurements. Note speed of response to step change.
   g. Confirm interaction of interlock and lockout systems.
   h. Provide set-point for every hydronic and air system pressure sensor. Coordinate closely with Division 23 09 00.
   i. Provide differential pressure set-point for dirty filter replacement for each filter bank installed in the building.
8. Sound and Vibration Levels: Test and adjust mechanical systems for sound and vibration in accordance with instructions of referenced standards.
9. Provide baseline acoustical and vibration testing for all air handlers, and large exhaust fans.
10. After deficiencies are corrected, retest the systems until acceptable values are obtained.
11. Permanently mark balancing devices spray paint indicating final position. Grease markers are not permitted.

J. Report:
   1. Report Format: Standard forms prepared by the referenced standard for each respective item and system to be tested, adjusted, and balanced. Include information indicated on standard report forms prepared by AABC or NEBB for each respective item and system, and schematic diagrams for each system or piece of equipment to accompany each respective report form. Bind report forms complete with schematic systems diagrams and other data in reinforced vinyl three-ring binders. Provide binding edge labels with project identification and a title descriptive of contents. Divide contents of binder into following divisions, separated by divider tabs:
      a. General Information and Summary
      b. Air Systems
      c. Hydronic Systems

d. Temperature Control Systems
e. Special Systems such as fume hood exhaust systems.
f. Sound and Vibration Systems
g. Recommendations.

2. Report Contents: Provide following minimum information, forms, and data:
   a. General Information and Summary:
      1) Inside cover sheet to identify testing, adjusting, and balancing agency, contractor, and project name. Include contact names, addresses, and telephone numbers.
      2) Certification sheet containing seal, address, telephone number, and signature of Certified Test and Balance Engineer.
      3) Listing of instrumentation used for procedures along with proof of calibration.
   b. Test Data: Report shall include the following data, in addition to certified field report readings taken during the balancing and testing operations. Include required or specified reading, first reading taken, and final balanced reading.
      1) Air Handling Units and Fans: Air handling unit, fan and motor nameplate information, type, drive sheave information (as installed and changed), and final belt number and size.
      2) Air Balance for Supply, Return, Relief, and Exhaust Systems:
         a) Outlets, Inlets, Diffusers, Registers, and Grilles: Size, reading orifice size, velocity in fpm, and design and final balanced air quantity in cfm.
         b) Terminal Boxes: Design and final minimum and maximum cfm settings including fan cfm on fan powered terminal boxes.
         c) Ducts: Size, velocity in fpm, and air quantity in cfm.
      3) Hydronic Balance:
         a) Water coil size and manufacturer.
         b) Boiler and burner nameplate information and flue gas analysis. Flue gas analysis shall be copy of manufacturer's analysis report.
         c) Chiller and motor nameplate information.
         d) Cooling tower and fan motor nameplate information.
         e) Pump and motor nameplate information. Include manufacturer's pump curves.
         f) Heat exchanger nameplate information.
         g) Snow melt circuits.
      4) Record thermal protection for all motors. Starter brand, model, enclosure type, installed thermal heaters and rating of heaters, required thermal heaters and rating of heaters if different from installed shall be recorded.
      5) Include sheet that reports method of balance, project altitude, and any correction factors used in calculations.
      6) Include a reduced set of contract drawings with all terminals (VAV boxes, outlets, inlets, coils, unit heaters, fans, etc.) clearly marked and all equipment designated.
      7) Prepare list of recommendations for correcting unsatisfactory mechanical performances when system cannot be successfully balanced.

3.2 TESTING, CLEANING AND CERTIFICATION

A. After cleaning, pressure tests, adjusting, and balancing are complete, each system shall be performance tested as a whole to verify that all items perform as integral parts of system, and temperatures and conditions are evenly controlled throughout building. Make corrections and adjustments as required to produce conditions indicated.

B. Provide four (4) copies of testing, adjusting, and balancing report bearing seal and signature of the TAB Engineer. The report shall be certification that systems have been tested, adjusted, and balanced in accordance with referenced standards; accurate representation of how systems have been installed; and accurate record of all final quantities measured.

C. Final Report:

1. Submit a preliminary report within 30 days of completed TAB work. Report shall include the following information.
   a. A general discussion preface section. This section shall summarize all abnormalities or problems encountered during the project and what course of action was taken. This summary should be assembled from the written progress reports described earlier, except that it will be expanded to include responses from the Engineer, the University Project Manager and Contractor regarding each problem indicated in the progress reports.
   b. Copies of correspondence if related to the performance and balance of the systems.
   c. Status of doors, windows and equipment static pressures during balance work.
   d. Reduced 11" x 17", readable, as-built drawings obtained from the University Project Manager. All devices and equipment shall be clearly labeled.
   e. Belt and sheave information, fan and motor nameplates information, full load operating voltage and amperage indicate sheave diameter as pitch diameter.
   f. Design and final actual cfm at each system terminal unit. Include terminal/size, inlet static pressure, temperature and velocities read to attain the design cfm.
   g. Overload protection for all motors shall be recorded. Starter and brand model, enclosure type, installed overload devices, original ratings, and set points (and revised device ratings and set points when application) shall be recorded.
2. Any corrective action shall be completed and the systems re-tested. The corrected system information shall be provided in the final report.
3. Final Report shall be completed within 30 days of preliminary report.

3.3 COMMISSIONING (DEMONSTRATION)

A. Upon request of the university Facilities Operations Representative, through the University Project Manager, the balancing firm shall demonstrate measured quantities of randomly selected equipment. The number of readings verified will not exceed 10 percent of the total in the report.

END OF SECTION 23 05 93